Mass Flux-Informed Remediation Decision Making at One of Canada's Most Polluted Sites

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Background

- Long history of steelmaking in Sydney (1901-1988)
- 700,000 tons of coal tar released into Muggah Creek (Sydney Tar Ponds, STPs)
    - PAHs
    - Metals
    - PCBs
- Govt. scientists reported widespread contaminated sediment & biota in STPs & Sydney Harbour in 1980s
- Remediation seen as solution

Remediation

- Numerous unsuccessful remediation attempts
- In 2004, Govts. of Canada & NS announced a $400 m project to clean up STPs & Coke Ovens
- STPs remediation consisted of solidification/stabilization (S/S) with cement
- Previously *mobile* contaminants effectively *immobilised* from migrating into SH

Monitoring Effects of Remediation

- **Environmental Impact Statement (EIS) & Joint Review Panel (JRP) concluded**
    - *"Remediation unlikely to cause significant negative environmental impacts with implementation of appropriate mitigation"*
- **Environmental Effects Monitoring (EEM) program designed to**
    - Determine effectiveness of mitigation
    - Verify effects predictions made in EIS
    - Designed to assess positive / negative changes potentially attributed to remediation
- **EEM program reviewed by key federal & provincial departments**
    - GW monitoring
    - SW monitoring
    - Marine EEM Program

Marine EEM Program

- **Water Quality (WQ)**
  - 24h auto sampler
  - Water grabs (surface & near bottom)
- **Mussel Tissue**
- **Sediment Quality**
  - Sediment chemistry (grabs & traps)
- **Crab Hepatopancreas Tissue**
- **Benthic Community**
  - Inter-tidal (5 transects using quadrats)
  - Sub-tidal (sieve analysis for benthic invertebrates)

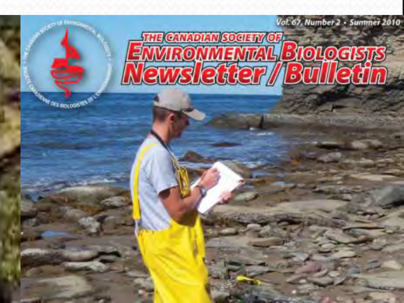
Detection of changes

Short term

Long term

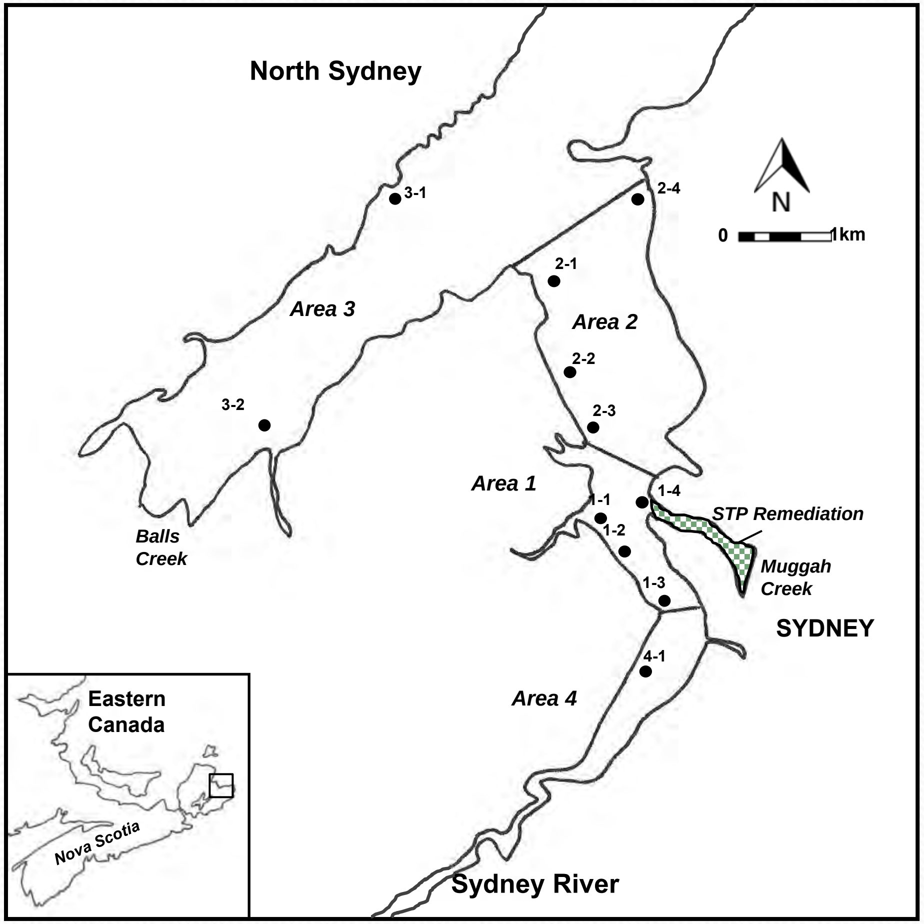






Marine EEM Sampling

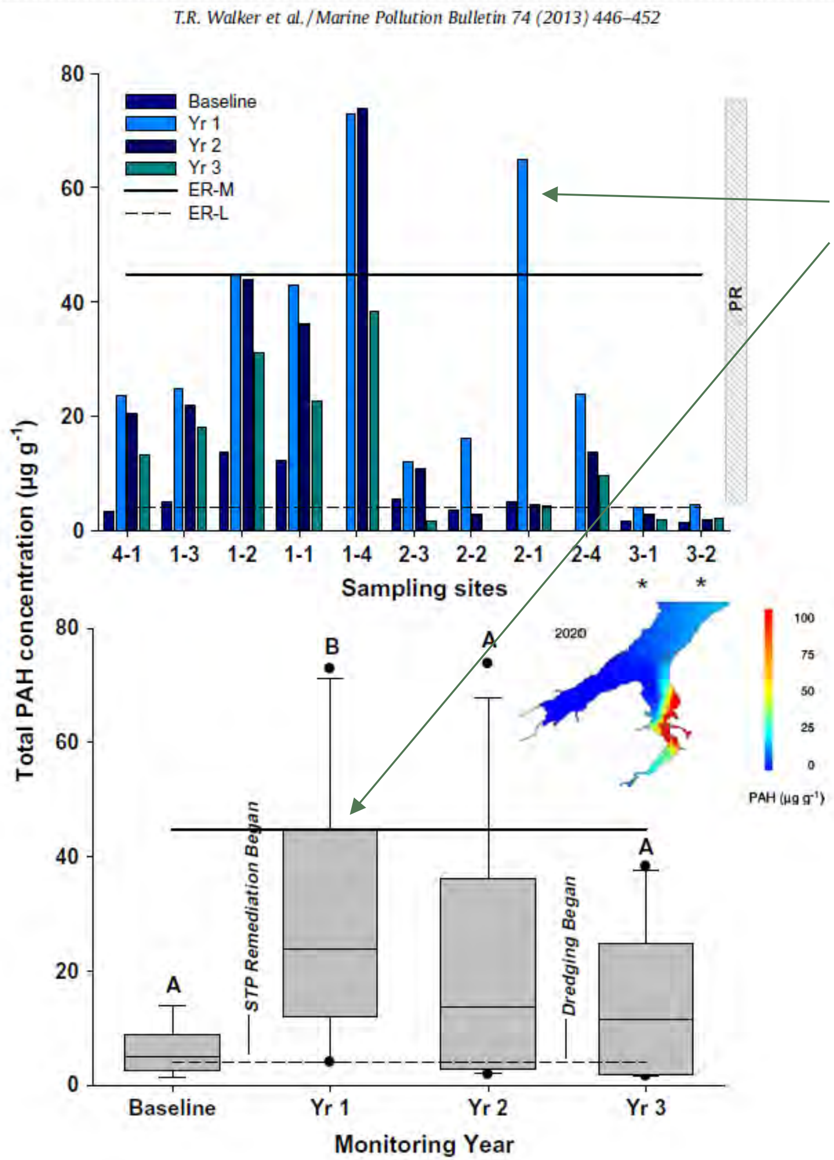
- **Spatial & temporal sampling**
- **Stations – 9-11**
  - Area 1 – Near-field
  - Area 2 – Mid-field
  - Area 3 – Far-field/reference
  - Area 4 – Sydney River Estuary
- **Sampling**
  - 2009 baseline
  - 2010 1st yr remediation
  - 2011 2nd yr remediation
  - 2012 3rd yr remediation



Sediment Quality: Grabs

- Grabs used for sediment sampling
- Surface sediments (0-1 cm) sampled annually at each station
- Sediments analysed for
  - PAHs
  - Metals
  - PCBs
  - TOC *etc*

Sediment Quality: PAHs



- **Significant increase in PAHs in Yr 1**
  - Some agencies called for termination of remediation after 1st year (Premature?)

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Science | Sciences

Maritimes Region

Canadian Science Advisory Secretariat
Science Response 2011/013

REVIEW OF THE SYDNEY TAR PONDS REMEDIATION PROJECT MARINE ENVIRONMENTAL EFFECTS MONITORING PROGRAM YEAR 1 RESULTS

Context

On February 4, 2011, Fisheries and Oceans Canada's (DFO) Environmental Assessment and Major Projects Division (EAMP), Maritimes Region, requested that DFO Science, Maritimes Region, provide advice regarding the Year 1 results of the Sydney Tar Ponds Remediation Project Marine Environmental Effects Monitoring Program (MEEMP), as well as the potential affects on MEEMP of dredging and infilling of Sydney Harbour that may be undertaken in support of the proposed Sydport container terminal. The request for science advice supports DFO EAMP's involvement as an expert authority in the Sydney Tar Ponds Remediation Project pursuant to the *Canadian Environmental Assessment Act*. Specifically, DFO EAMP asked:

1. Are the conclusions of each Sydney Tar Ponds Remediation Project marine monitoring method valid based on the Year 1 monitoring results and baseline observations?

2. Should the marine monitoring methods be changed, based on the Year 1 monitoring conclusions, to better improve the monitoring program?

DFO CSAS strong concerns & EC even requested cessation of remediation activities!

factors of 2 to 10 at all sampling locations and for all individual PAHs in Year 1 of the MEEMP monitoring program compared to the pre-construction phase of the Tar Sands remediation project.

- The increases observed in sediment PAH, but not in metal and polychlorinated biphenyl, levels indicate they are associated with transport from the Tar Ponds remediation site into the harbour by water or atmospheric pathways. The detection of these PAH increases in harbour sediments attests to the general value and utility of the MEEMP.

Sediment Quality: PAH Increases?

- **Calculated Mass Flux to determine release of contaminants from site**
  - 3 yrs of mass flux
- **Grabs & DFO gravity SLO-CORER compared**
- **Triplicate sampling to assess intra-station variation**
- **Other potential sources using LOE approach**
  - Bulk coal storage facility
  - Uncovering events?
  - Ship propeller wash

Estimates of PAH Mass Flux to SH

- **Contaminant mass flux techniques help understand "*mobile*" vs. "*immobile*" contaminants**
  - Gibbs & Santillan (2009); Suthersan et al. (2010)
  - Flux-informed decision-making helps develop remediation end point goals aimed at reducing off-site exposure & risk
- **Reviewed numerous historical flux studies at STPs**
  - Government reports
  - ERA studies
- **Performed our own mass flux study (3 yrs) during remediation at STPs**
  - Dillon (2011, 2012 & 2013)
- **Compared against independent engineers flux estimate**
  - CRA (2011)

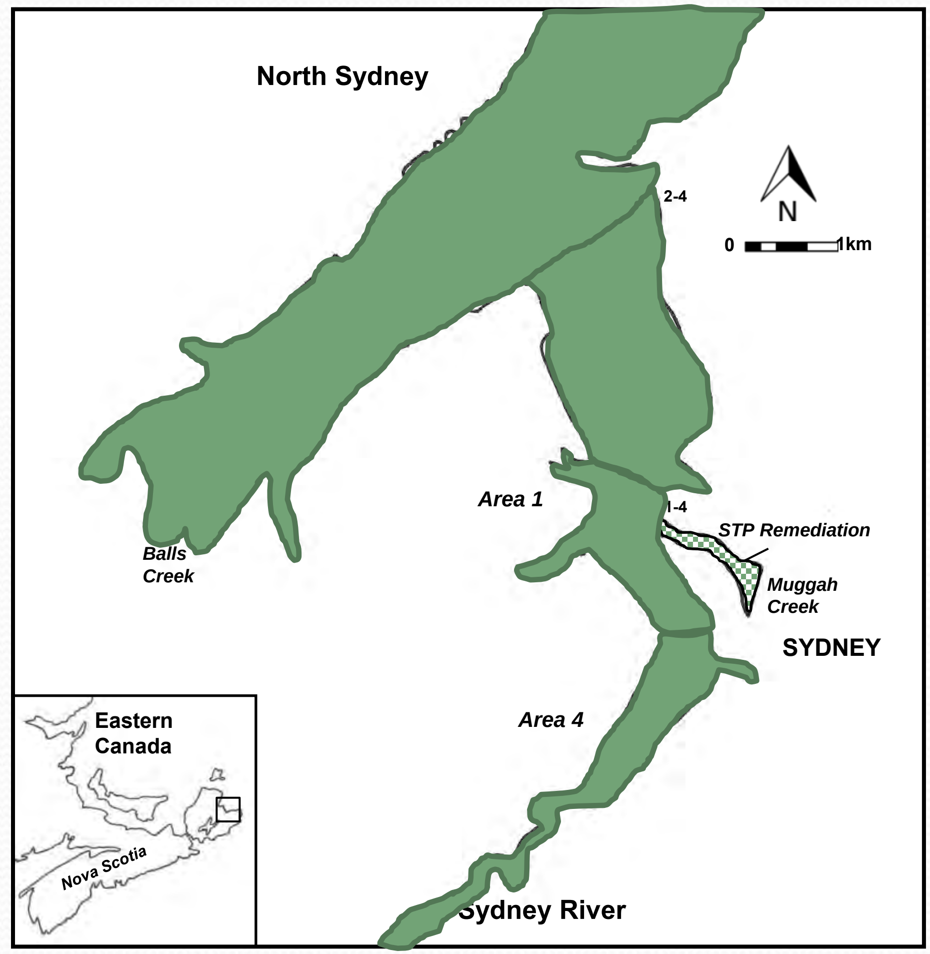
Assumptions for PAH Flux Estimates

- **Marine**
  - Δ conc. over 15 months (Jul 2009-Oct 2010)
  - Mean concs. calculated/m^2 for each area over 0-1 cm horizon
  - Surface area determined for each area
- **SW**
  - Mass loadings calculated for Jan-Dec 2010
  - SW flow data provided by STPA represents inputs to North Pond
  - Concs. based on outgoing tide samples collected within ~2 h of low tide
  - Loadings based on mean, min. & RDLs concs.
  - 20% increase in total flow added to account for overflow at South Pond & overland flow
- **GW**
  - GW from eastern shore of North Pond assumed to contribute mass discharge (5 wells)
  - Mean concs. from quarterly sampling events used (Mar, Jun, Sep)
  - Hydraulic gradient of 0.005 used based on 2010 GW contours
  - 2.5 m of plume (aquifer) thickness in intertidal zone assumed

Total PAH Accumulation

- **Total PAH accumulation from 2009 - 2010**
  - Area 1 – 363 kg
  - Area 2 – 916 kg
  - Area 3 – 469 kg
  - Area 4 – 189 kg

- **<u>Total PAH ~2000 kg !!!!</u>**



Calculated Mass Discharge to Sydney Harbour Year 3 (2012)															
Sample Area	**Total Suspended Solids**	**Aluminum**	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Mercury**	**Nickel**	**Zinc**	**Total PAH**	**Benzene**	**Arsenic**	**Lithium**	**Sulphate**	**PCBs**
units	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**
Mass Discharge for Surface Water (average)	1073710	22149	6	484	15260	1658	1.0	164	6962	56	--	206	3151	133150816	--
Mass Discharge for Surface Water (minimum)	96454	2845	1	48	116	68	0.6	154	246	0	--	30	92	4629797	--
Mass Discharge for Surface Water (RDL)	96454	241	8	48	96	48	0.6	145	241	22	48	29	48	96454	2
Mass Discharge for Groundwater	--	--	0.00001	0.0001	0.0007	0.0002	0.00002	0.0003	0.002	0.002	0.0002	0.0003	0.0065	38.48	--
Calculated Accumulated Mass in Sydney Harbour Year 3 (2012) ***Corrected for 12 months (e.g., change in concentration between July 2011 to July 2012)***															
Area 1 Sediments	--	--	-3.9	--	-458	-579	-2.2	--	-1175	-221	--	104	--	--	-4
Area 2 Sediments	--	--	-0.2	--	-376	-775	-0.9	--	-1234	-118	--	-203	--	--	2
Area 3 Sediments	--	--	-9.4	--	426	426	0	--	1789	-61	--	1619	--	--	12
Area 4 Sediments	--	--	-0.3	--	-47	-19	-0.5	--	0	-69	--	19	--	--	-2

Calculated Mass Discharge to Sydney Harbour Year 2 (2011)															
Sample Area	**Total Suspended Solids**	**Aluminum**	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Mercury**	**Nickel**	**Zinc**	**Total PAH**	**Benzene**	**Arsenic**	**Lithium**	**Sulphate**	**PCBs**
units	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**
Mass Discharge for Surface Water (average)	257485	4600	29	1051	11408	1937	0.58	1432	11633	17	--	355	3117	137015891	--
Mass Discharge for Surface Water (minimum)	25128	1256	2	60	628	276	0.33	754	1307	0	--	178	5031	18092487	--
Mass Discharge for Surface Water (RDL)	50257	1256	1	251	503	251	0.33	1754	1256	12	25	151	251	502569	--
Mass Discharge for Groundwater	--	--	0.0005	0.0008	0.006	0.0003	0.000003	0.002	0.070	0.004	0.0006	0.0004	0.011	50.49	--
Calculated Accumulated Mass in Sydney Harbour Year 2 (2011) ***Corrected for 12 months (e.g., change in concentration between October 2010 and July 2011)***															
Area 1 Sediments	--	--	1	--	81	246	1	--	401	-33	--	-24	--	--	-11
Area 2 Sediments	--	--	0	--	-185	-617	-2	--	-1022	-750	--	-132	--	--	-3
Area 3 Sediments	--	--	26	--	-1193	-1108	0	--	-4346	-335	--	-85	--	--	5
Area 4 Sediments	--	--	-4	--	-179	-245	-1	--	-377	-29	--	9	--	--	0

Calculated Mass Discharge to Sydney Harbour Year 1 (2010)															
Sample Area	**Total Suspended Solids**	**Aluminum**	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Mercury**	**Nickel**	**Zinc**	**Total PAH**	**Benzene**	**Arsenic**	**Lithium**	**Sulphate**	**PCBs**
units	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**
Mass Discharge for Surface Water (average)	774639	12339	27	7547	23402	2292	1.3	3014	60541	97	--	--	8825	133335203	--
Mass Discharge for Surface Water (minimum)	228115	3878	8	912	479	471	1.2	297	2965	8	--	--	2129	34217186	--
Mass Discharge for Surface Water (RDL)	152076	3802	1	76	152	760	1.0	2281	380	35	76	46	760	7603819	4
Mass Discharge for Groundwater	--	--	0.0003	0.0001	0.003	0.0002	--	--	0.05	0.005	0.0006	0.0004	0.012	46	
Calculated Accumulated Mass in Sydney harbour Year 1 (2010) ***Corrected for 12 months (e.g., change in concentration between July 2009 to October 2010)***															
Area 1 Sediments	--	--	3	--	36	-94	-3	--	94	363	--	67	--	--	1
Area 2 Sediments	--	--	1	--	-70	-81	-1	--	-247	916	--	141	--	--	2
Area 3 Sediments	--	--	0	--	0	1449	0	--	852	469	--	341	--	--	0
Area 4 Sediments	--	--	3	--	94	94	-1	--	189	189	--	19	--	--	1

Trends between yrs 1, 2 and 3 Mass Flux

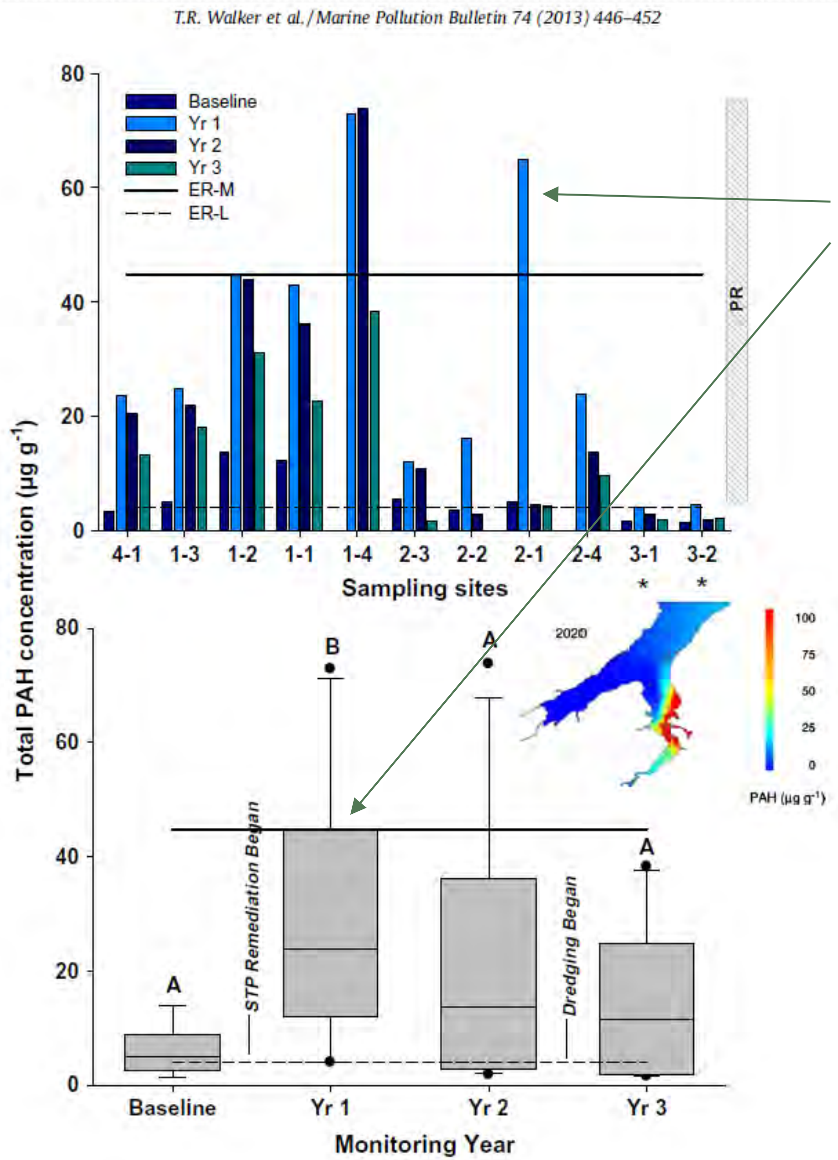
D	D = Decreasing
PD	PD = Potentially Decreasing
S	S = Stable
PI	PI = Potentially Increasing
I	I = Increasing

Estimates of PAH Fluxes to SH

- **Previous (300-800 kg/yr)**
  - 1989 – 767 kg/yr (Lane & Associates, 1991)
  - 2000 & 2001 – 793 kg/yr (JDAC, 2002)
  - 2000 & 2001 – 289 kg/yr (Lee et al., 2002)

- **During Remediation (<120 kg/yr)**
  - 2010 – 97 kg/yr (Dillon, 2011)
  - 2010 – 119 kg/yr (CRA, 2011)
  - 2011 – 17 kg/yr (Dillon, 2012)
  - 2012 – 56 kg/yr (Dillon, 2013)

Sediment Quality: PAHs

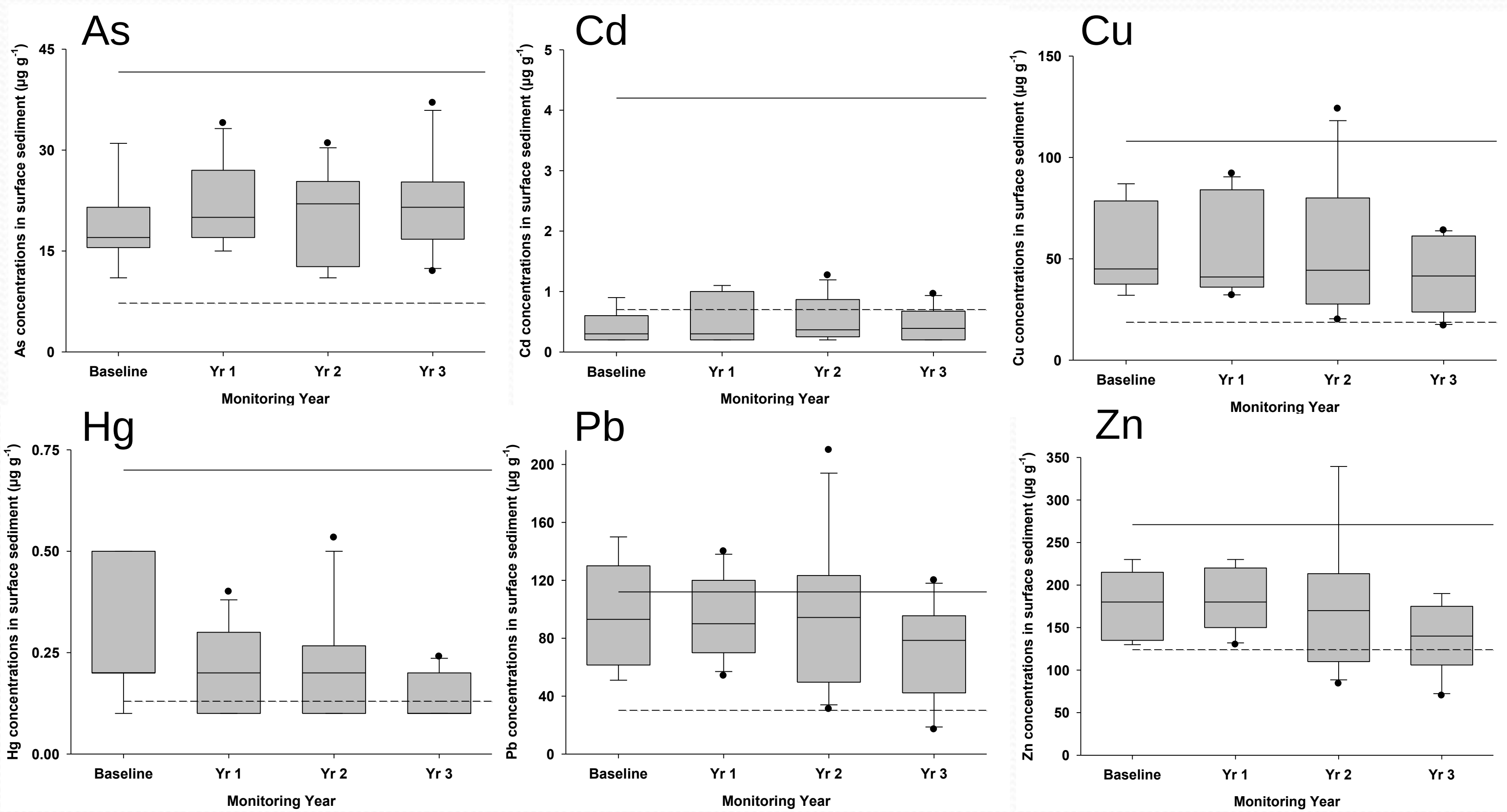


- **Significant increase in PAHs in Yr 1**
  - Some agencies called for termination of remediation after 1st year (Premature?)
- **Subsequent monitoring showed a continued decrease in PAHs**
  - Not significantly different from baseline
  - Within predicted ranges reported by Smith et al. (2009)
- **EIS prediction of no significant environmental impacts in SH confirmed?**

[PAH] Increases During yr 1

- **Onsite releases from remediation activities?**
  - A more localized sediment PAH signature expected
  - ~100 kg/yr PAHs estimated flux from STPs, considerably lower than ~800 kg/yr flux estimated by JDAC (2002) & much lower than would be required to cause PAH increases in yr 1 (2000 kg)
- **Large scale uncovering event of contaminated sediments?**
  - 5 major storms between July 2009 & October 2010
  - Ship propeller wash – but not at all sites?
- **Results from 2009 could have been "unusually" low?**
  - Burial from less contaminated shallow channel sediments
- **Other potential sources (eg. bulk coal storage facility)**
  - Although this facility was also present in 2009?

Sediment Quality: Metals



- **Little apparent temporal variation**
- **EIS prediction of no significant environmental impacts in SH confirmed?**

Heavy Metal(s) Lives On!

Contaminants in Various Media

Media	Detection of Effects	PAH	PCB	As	Cd	Cu	Hg	Pb	Zn	JRP Significance	Reference
Water quality	Short term	→	→/nd	→	↓	→	→	→	→	Not significant	(Dillon 2013)
Blue mussels		→/nd	→/nd	→	→	→	→	↑	↑	Not significant	(Walker et al. 2013b)
Surface sediment		→	→	→	→	→	↓	→	↓	Not significant	(Walker et al. 2013c,d)
Rock crabs	Longer term	→/nd	↓	→	→	→	→	→/nd	→	Not significant	(Walker et al. 2013a)

→ = Stable
↓ = Decreasing
↑ = Potentially increasing
nd = Not detected

Walker, T.R., et al. (2013a) Legacy contaminant bioaccumulation in rock crabs in Sydney Harbour during remediation of the Sydney Tar Ponds, Nova Scotia, Canada. ***Mar. Pollut. Bull.*** 77, 412-417.
Walker, T.R., et al. (2013b) Blue mussels (Mytilus edulis) as bioindicators of stable and improving water quality in Sydney Harbour during remediation of the STPs, NS, Canada. ***Water Qual. Res. J. Can.*** 48, 358-371.
Walker, T.R., et al. (2013c) Monitoring effects of remediation on natural sediment recovery in Sydney Harbour, Nova Scotia. ***Environ. Monit. Assess.*** 185, 8089-8107.
Walker, T.R., et al. (2013d) Environmental Recovery in Sydney Harbour, Nova Scotia: Evidence of Natural and Anthropogenic Sediment Capping. ***Mar. Pollut. Bull.*** 74, 446-452.
Dillon (2013) Final Marine Report for Year 3 Construction. Submitted to the Sydney Tar Ponds Agency.

Summary

- **Only 17-97 kg/yr total PAH discharged in SW during 3 yrs monitoring**
  - GW responsible for negligible quantities (0.002-0.005 kg/yr)
- **Independent PAH flux study in yr 1 estimated 119 kg/yr (CRA, 2011)**
  - Compared favourably to our 97 kg/yr estimate during same period
- **PAH flux from STPs during remediation is in stark contrast to ~2000 kg loading in harbour sediment PAH concentrations during 2010**
- **Mass flux estimates during remediation was much lower than ~800 kg/yr PAHs discharged from STPs in 2001 (JDAC, 2002)**
  - At same time, govt. studies demonstrated on-going reduction in PAH concs.

Summary

- **This mass flux study informed remediation decision making by helping all stakeholders better understand "*mobile*" vs. "*immobile*" contaminants**
  - Calls for termination of remediation by regulators was premature

- **S/S remediation *immbolised* contaminants**

- **Flux results corroborated in a separate PAH forensic assessment which found a common source of PAHs for soils, marine & aquatic sediments**
  - Specific PAH forensic assessment results will be discussed in a separate platform presentation at this conference

Thank You

Sydney Tar Ponds Agency

Public Works and Government Services Canada

Travaux publics et Services gouvernementaux Canada

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